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Rice Fields Chemical and Physical Properties and the Implications on Breeding Strategies

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ABSTRACT

Soil related constraints are major limiting factors in crop production in the Sahel. The objective of this study was to assess the properties of farmer's fields soil and irrigation water in Niger and the implications in rice improvement. Composite soil samples were collected from irrigated and non-irrigated fields. Sample of irrigation water was also collected. Physical and chemical analyses were performed in the laboratory. The results showed that most of rice fields were clayey and the non irrigated ones were mostly sandy. The soils were acidic and saline, the electrical conductivity ranged from 2.2 to 16.5 decisiemens per meter. The T-test showed that total dissolved salt, sodium adsorption ratio, cation exchange capacity, and organic matter percentage were significantly higher in irrigated fields than non-irrigated fields. The irrigated soils pH varied from 3.2 to 6.8, the electrical conductivity was greater than 4, and the sodium adsorption ratio was below 13 while the exchangeable sodium percentage was below 15. The irrigation water samples varied in term of ion content from site to site. The total sodium quantity estimated to be deposited varied from 87 kg/ha/year to 218 kg/ha/year. Rice fields' soils are saline and are getting worsened by irrigation water that contains salt. Therefore, the development of rice varieties that could withstand osmotic and ionic salt stress is necessary for sustainable production in the Sahel ecozone.

Introduction

Niger is a Sahelian country that is characterized by extremely fragile and harsh natural environments (FAO, 2008). About 80% of the country land is covered by the Saharan desert, with only about 15% of arable lands for crop production (Anonymous, 2016). This arable land is concentrated mainly in the South of the country and more than 80% of the Niger's population rely on the crops produced (MAE, 2001).

Farmers in Niger have been experiencing, low productivity on their fields for decades due to several constraints, including: high occurrence of pests, weeds and diseases, drought, floods, poor seed management and soil problems (Norman and Kebe, 2007). Moisture stress is the most important constraint which limits the productivity of the soils. This is a result of inadequate and poor distribution of rainfall. In an attempt to solve the water availability problem, rice farmers irrigate their fields with river water. Consequently, farmlands have now become saline and alkaline due to a prolonged use of irrigation water (Sant'Anna, 2000; FAO, 2009). According to Jacques *et al*.(Jacques *et al*., 1994) the sahelian countries in Africa are especially affected by salinization processes, along the large rivers such as the Niger and the Senegal. Salinization has already affected crop productivity in 20–30% of irrigated lands with an additional 1.5 million hectares affected annually(Karuppan and Minh-Long, 2010).

With the continuous use of irrigation water to sustain crop yields, it is anticipated that more of Niger's soils along river banks will be salinized. Additionally, saline soils would see more increase of the levels of salinity. There is, therefore, the need to have pragmatic approach to get round the problem.

One of the feasible ways of addressing the problem is to develop salinity tolerant crops through breeding. Knowledge on the characteristics of irrigated field soils and irrigation water properties are critical for making breeding decision. This study aimed at surveying rice farmers irrigated fields to ascertain the extent of salinity in soils, determine the contribution of irrigation to field's salinity, and assess the fertility level to understand the implications in rice breeding.

Material and Methods

The study was conducted in 2012 across three regions of western Niger, located in semi-arid zone and crossed by Niger River over a distance of 550 km (FAO, 2007). Since 2012, no known study has been conducted in this area for the purpose. These regions are Gaya (11° 53' 16" N, 3° 26' 48" E), Niamey (13° 40' 0" N, 1° 47' 0" E) and Tillabery (14° 12' 42" N, 1° 27' 11" E). Gaya is characterized by an average maximum annual temperature of 36°C and annual rainfall of 883 mm. Niamey has average maximum annual temperature of 36.8°C and annual rainfall of 505 mm. Tillabery is characterized by an average maximum annual temperature of 37.62°C and annual rainfall of 417 mm (INS, 2010). Ten villages were randomly sampled from these regions for the study.

Ten farms, each from a different irrigation scheme along the bank of the r river were selected for the study. The selected farms were from Gaya Amont, Gaya Aval, Sokondji, Sebery, Ndounga, Saga, Toula and Bonfeba.

Composite soil samples from the plough depth (20 cm) were taken from each site. Composite soil samples were also taken from similar soils adjacent to the sites which have had no history of irrigation. The latter samples served as control. After collection, the soil samples were air dried ground and passed through a 2 mm sieve to obtain the fine earth fraction. The fine earth fraction was then stored in plastic bags for laboratory analyses.

The river water used to irrigate the rice fields was sampled by taking into account the two different cropping seasons (dry season and rainy season). Five water samples were taken in the dry season: three from Tillabery area, and two from Gaya. Two other samples were collected in Niamey area in the rainy season. In addition, one sample was collected from pipe borne water. Thus, a total of eight samples were taken for laboratory analyses.

The soil and water samples were analyzed in the soil laboratory of INRAN (National Institute of Agricultural Research, Niger).

The soil pH and electrical conductivity were measured using electrometric method (soil: water 1:1). The total Nitrogen and available P were measured using Macro Kjeldhal digestion and Olsen's method (Olsen *et al*., 1954) respectively.

The exchangeable bases, the cation exchange capacity, calcium carbonate, texture and total dissolved ions (TDS) were also measured.

For particle size distribution, 40g of the fine earth fraction of the soil was weighed into a plastic bottle and 100 mL of 5% calgon [sodium hexametaphosphate (NaPO3)6)] solution was added. The content of the bottle was then shaken on a mechanical shaker for 2 hours after which it was transferred into a 1.0 litre measuring cylinder and topped up to the mark with distilled water. The suspension was then agitated with a plunger for five minutes and the density of the suspension (silt and clay) was taken using a hydrometer M100 0.700 To 0.800 (from Camlab United kingdom). The hydrometer reading of the suspension was taken again after eight hours (clay). The temperatures of the suspensions, T_1 and T_2 were recorded during the 5 minute and 8 hour hydrometer readings respectively. The contents of the cylinder after the eight hour reading were emptied onto a 47-µm sieve. The sand retained on the sieve was then washed off into a moisture can and dried at 105 ^oC for 24 hours, after which the dry weight of the sand was recorded. Blank sample hydrometer readings at five minutes and eight hours respectively were also taken for the 5% calgon topped up to 1.0 L. The particle size distribution was then determined using the formula below (Day, 1965).

Temperature of the suspensions at T_1 and T_2 = 28°C

$$\% \text{ Clay and Silt} = \frac{(\text{5 minute reading} - \text{correction for temperature})}{\text{oven dry mass of sample}} \times 100 \quad (1)$$

$$\% \text{ Clay} = \frac{(\text{8 hour reading} - \text{correction for temperature})}{\text{oven dry mass of sample}} \times 100 \quad (2)$$

$$\% \text{ Silt} = \% (\text{Clay and Silt}) - \% \text{ Clay} \quad (3)$$

$$\% \text{ Sand} = \frac{(\text{oven dry weight of particles retained on the 47 µm sieve})}{\text{oven dry mass of sample}} \times 100 \quad (4)$$

Temperature effects on density of the soil particles were accounted for using the relation provided by Day (Day, 1965). For every 1°C increase in temperature, above 19.5 °C, there is an increase of 0.3 in the density of the particles in suspension.

Correction for temperature = blank hydrometer reading increase in weight of particles

The pH of the fine earth of the soils was determined in a 1:1 soil ratio. A 10 g soil was weighed and 10 mL of 1 M KCl added, stirred vigorously and allowed to stand for 30 minutes. A microprocessor pH 213 meter (Hanna Instruments Inc., 584 Park East Drive, Woonsocket, Rhode Island, 02895, USA) was calibrated, and then inserted into the supernatant of the soil solution and the pH read.

Ten grams of the soil sample was weighed into a beaker and 10 mL of distilled water added, to give soil water ratio of (1:1). This ratio was used to ensure that soil paste with the right consistency was obtained for immersion of electrode. The mixture was then stirred several times for about 30 minutes and left to stand for about an hour to equilibrate with the temperature in the instrument room. The electrical conductivity was then determined using the "Solu Bridge" (Beckman, USA) electrical conductivity meter at cell constant K = 1.06 at 25 ^0C.

Total N of the fine earth was determined by using the Kjeldahl digestion procedure as outlined by Anderson and Ingram (Anderson and Ingram, 1993). A 1.00 g of 0.5 mm sieved fine earth was weighed into a digestion tube, followed by addition of 5 mL concentrated H_2SO_4. The mixture was heated at low heat on a digestion block for 30 minutes, and then 2 mL of hydrogen peroxide was added. The heating temperature was then increased to 360 ^oC and maintained till the mixture changed to a permanent colorless solution. The digest was cooled, transferred and made up to volume with the aid of distilled water in a 100 mL volumetric flask.

A 20 mL aliquot was transferred into a tecator distillation flask, 10 mL of 40% NaOH solution added and distilled. The ammonia liberated was condensed and collected in a 10 mL boric acid to which bromocresol green and methyl red solution indicator had been added. The distillate was then back titrated with 0.01 M HCl solution. Similar procedure was adopted for a blank which had no soil sample to account for traces of N if any, in the reagents and water used. The concentration of N in the soil was estimated from the number of moles of HCl consumed in the reaction with ammonium borate formed when the ammonia was trapped in boric acid.

An aliquot of the sample used to determine total nitrogen content of the soil was taken for phosphorus determination using Murphy and Riley (Murphy and Riley, 1962). An aliquot of 1 mL was taken into a 50 mL volumetric flask and a drop each of P-nitrophenol and ammonium hydroxide was added. Eight mL of a solution containing concentrated sulphuric acid, ammonium molybdate, potassium antimony tartrate, and ascorbic acid was added. Using distilled water, the content was topped up to the 50 mL mark. The P concentration was determined on a Philips' UV spectrophotometer at a wavelength of 712 nm.

For the cation exchange capacity determination 5 g of the fine fraction of the soil were weighed into an extraction bottle and 50 mL of 1.0 M ammonium acetate at pH 7.0 added. The contents were then shaken for 30 minutes and filtered through a Number 42 Whatman filter paper. The filtrate was then kept for exchangeable bases determination. The non-adsorbed NH_4^+ was then washed off with methanol and the NH_4^+ saturated soil leached four times with acidified 1.0 M KCl. A 10 mL aliquot was transferred into a tecator distillation flask and distilled to liberate NH_3 into boric acid. 4.3.3.6. The distillate was then back titrated with 0.01 M HCl solution. The CEC of the soil was determined from the concentration of NH_4^+ estimated from the number of moles of HCl consumed in the reaction with ammonium borate formed when the ammonia was trapped in boric acid.

The exchangeable bases in the filtrate were determined by reading the concentration of Na, K, Ca and Mg on a Perkin Elmer (Mundelein, Illinois, USA) Atomic adsorption spectrophotometer (AAS). The base saturation of the soil was then calculated as the sum of the bases over the total CEC of the soil.

The concentrations of cations, Ca, Mg, K and Na in water samples were read on the AAS. The levels of carbonate, sulphate and chloride were calculated using an Elit ion analyser. Sodium Adsorption Ratio (SAR) was calculated based on the sodium, calcium and magnesium levels in the water. It was calculated using the equation (Mohsen *et al.*, 2009):

$$\mathrm{SAR}=\frac{Na}{\left(\frac{Ca+Mg}{2}\right)^{1/2}}$$

Total dissolved ions in the water was measured as the sum of ions present in a sample of water, and was used as an estimate of the total dissolved ions[15]. The measured ions were Sodium (Na+), Calcium (Ca++), Magnesium (Mg++), Potassium (K+) Chloride (Cl-), Sulfate (SO4--) and Bicarbonate (HCO3-).

The total salt deposited per hectare of irrigated field was obtained by multiplying the salt per liter content (mg L^{-1}) by the estimated water volume per ha for each cultivation cycle.

The quantity of water (Qw) per season per hectare was calculated by using the formula (ONAHA non published doc):

$$Qw=\frac{(\text{Volume of water pumped} * \text{flow per hour} * \text{Number of hour per day} * \text{irrigation days per season}) - \text{wasted water}}{\text{Area of irrigated scheme}}$$

The wasted water was estimated to be 20% of the total (ONAHA non published doc).

***Data analysis*:**

Table 1. Soil texture of irrigated fields and none irrigated fields

	Irrigated fields			Non-Irrigated fields		
	Clay (%)	Silt (%)	Sand (%)	Clay (%)	Silt (%)	Sand (%)
Gaya Aval	44.6	37.2	18.2	28.3	41.5	30.2
Gaya Amont	48.1	41.2	10.7	11.3	29.7	70.2
Diambala	32.2	52	15.7	21.2	46.8	32
Sakondji Birni	48.6	20.7	31.7	45.2	41.1	13.8
Saguia	41.8	43.9	14.2	4.3	20.5	75.2
Saga	11.6	13.1	75.3	7	14.1	79.8
Bonfeba	12.5	19.7	67.7	7.6	10.1	82.4
Sebery	48.4	26.6	25	6.3	8.8	84.9
Toula	11.8	14.7	73.5	14.1	18.7	67.2
Ndounga	51.4	25.8	22.8	4.5	8.5	87.2

The pH of both irrigated and non irrigated soils in the communities selected for the study are shown in Table 3. Apart from the soil at Bonfeba which was neutral in term of pH all the soils were acidic (pH < 7). The lowest pH in KCl of 3.5 was recorded in the two localities of Gaya. The pH in KCl at Saguia and Sakondji Birni were strongly acidic with pH below 5. In general, there was no significant difference in pH between irrigated and non irrigated plots within each selected field.

Table 2. Statistics of soils textural characteristics

	Mean	Variance	Standard deviation	T-test	Probability
Clay-IF	35.10	282.6	16.81		
Clay-NIF	14.98	173.5	13.17	2.98	0.001
Silt-IF	29.49	177.0	13.31		
Silt-NIF	23.98	217.1	14.73	0.88	0.392
Sand-IF	35.48	679.0	26.06		
Sand-NIF	62.29	710.5	26.66	2.27	0.035

IF=irrigated field, NIF= non irrigated fields

Genstat software (VSN International, United Kingdom) version 18 was used for statistical analysis. T-test and mean difference confidence interval approach were used for means separation. Principal component analysis (PCA) was also use.

Results

Large variability exists within irrigated field soils and among irrigated and non irrigated soils texture (Table 1). This variability exists also within non irrigated fields. Irrigated soils of Gaya Amont, Gaya Aval, Sokondji, Ndounga Sebery and Ndounga were predominantly composed of clay and silt. At Saga, Toula and Bonfeba, sand was the main component. Most non- irrigated fields (NIF) are sandy soils. Irrigated fields soils were significantly different from non-irrigated fields' soils (at 0.001 probability level) in terms of clay content. Significant differences were also observed among the two types of fields in terms of sand content (at 0. 035 probability level) (Table 2). However, in terms of

Table 3. Chemical properties of irrigated and none irrigated fields

Sites		pH	SAR	PAR	CEC (meq/100 g)	EC (dS/m)	Na/k (%)	TDS (meq/100 g)
Gaya Aval	IF	3.4	2.19	0.06	18.99	6.5	34.2	24.94
	NIF	3.3	0.96	0.09	9.2	3.4	11.2	11.03
Gaya Amont	IF	3.2	1.82	0.07	14.88	5.7	22.2	20.23
	NIF	3.5	1.54	0.06	8.68	3.0	31.8	11.37
Diambala	IF	4.6	4.91	0.01	17.95	5.4	75	19.78
	NIF	5.8	1.04	0.66	7.73	5.3	7.4	14.66
Sakondji Birni	IF	4.4	4.42	0.05	13.92	5.2	22.5	16.12
	NIF	4.5	1.08	0.06	8.9	2.7	71.7	16.32
Saguia	IF	4.4	0.83	0.07	16.91	7.7	12.1	19.50
	NIF	4.1	0.68	0.04	11	5.2	16.7	11.31
Saga	IF	5.4	11.38	0.10	11.94	9.0	118.6	36.85
	NIF	5.5	0.94	0.23	8.13	2.2	4	8.67
Bonfeba	IF	7.2	1.83	0.25	19.09	16.5	7.8	11.28
	NIF	6.8	1.65	0.06	8.98	8.5	28.8	22.80
Sebery	IF	5.2	2.46	0.04	18.96	5.6	60.8	25.57
	NIF	5.6	0.49	0.05	17.75	4.6	10.8	17.96
Toula	IF	5.1	2.87	0.03	19.67	7.9	108.8	27.17
	NIF	5.4	0.49	0.09	20.2	7.7	5.4	20.50
Ndounga	IF	4.4	1.33	0.03	23.07	6.9	40	28.39
	NIF	5	0.81	0.12	10.16	6	6.8	10.66

IF=irrigated field, NIF= non irrigated fields

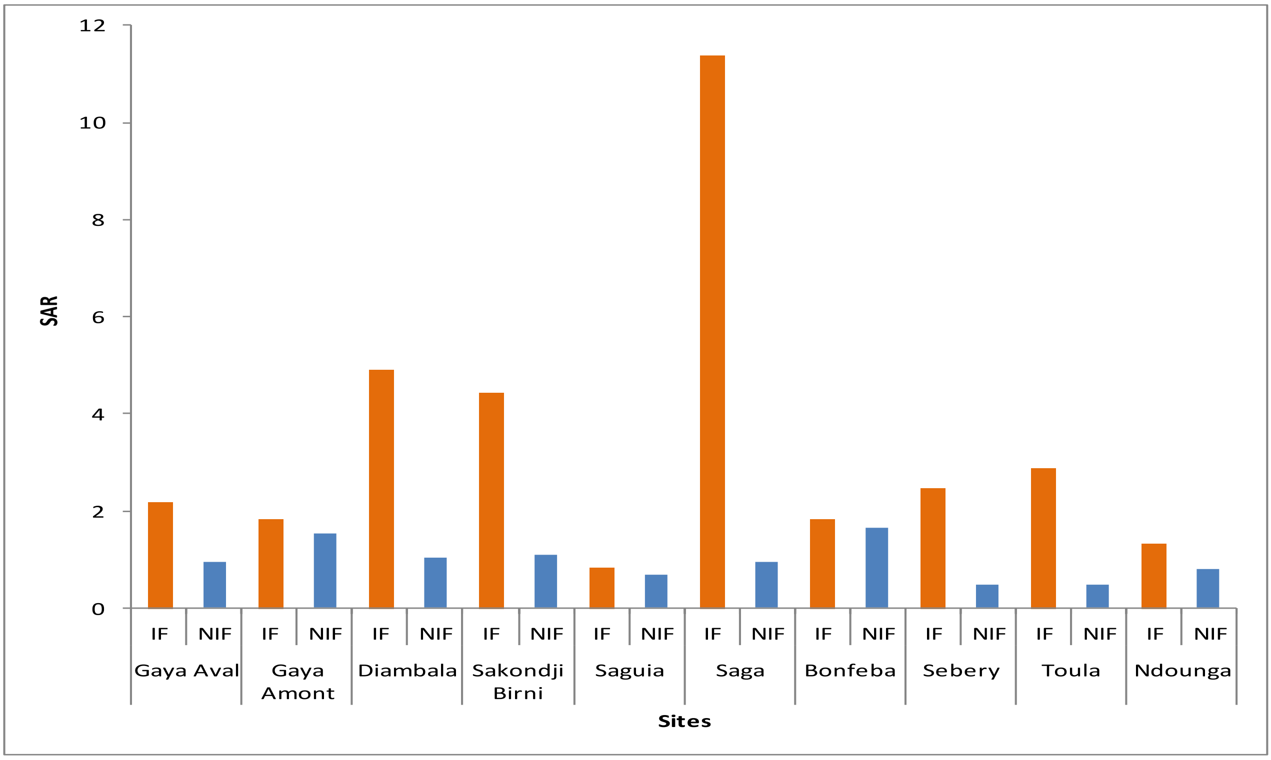

Figure 1. Sodium Adsorption Ratio of irrigated and non irrigated fields

Table 4. statistics of soil chemical propreties

	Mean	Variance	Standard deviation	T-test	Probability
pH-IF	4.73	1.26	1.12		
pH-NIF	4.95	1.20	1.10	0.44	0.66
SAR-IF	3.40	9.50	3.08		
SAR-NIF	0.97	0.15	0.39	2.48	0.001
PAR-IF	0.0710	0.005	0.09		
PAR-NIF	0.1460	0.036	0.19	1.18	0.026
CEC-IF	17.54	10.42	3.227		
CEC-NIF	11.07	18.54	3.227	3.80	0.001
EC-IF	7.640	11.24	3.35		
EC-NIF	4.860	4.48	2.117	2.22	0.0004

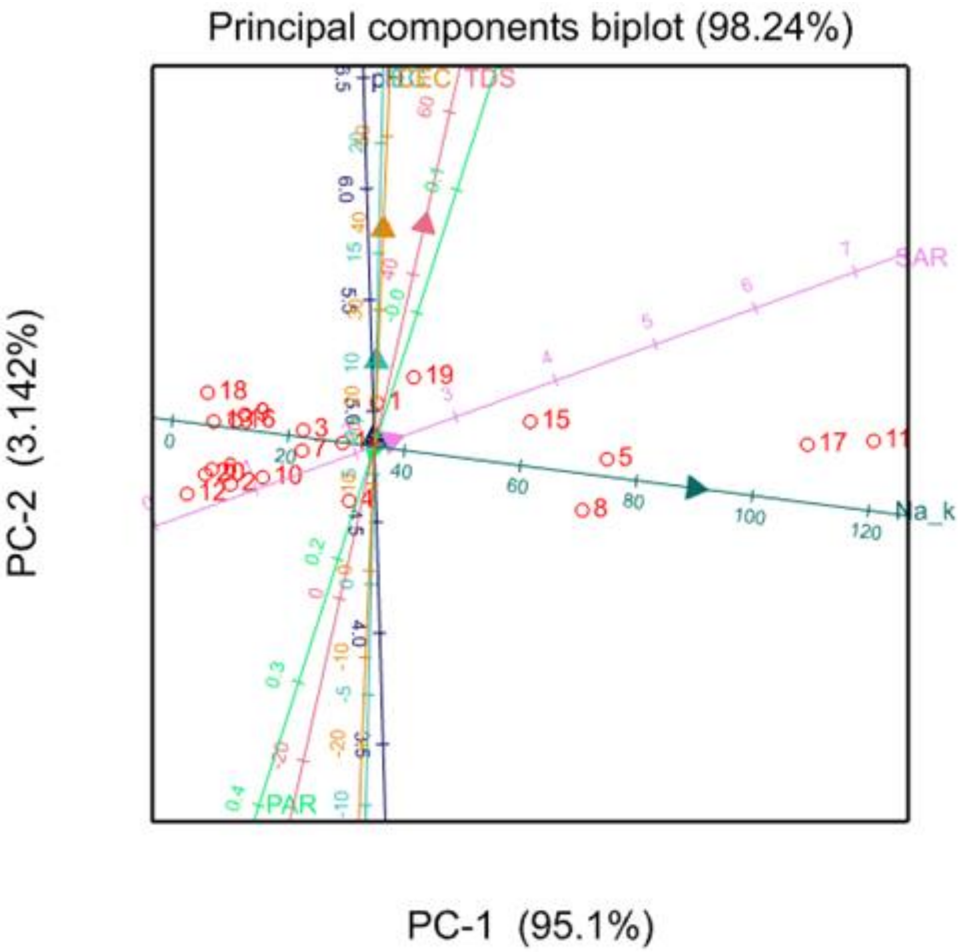

Figure 2. Principal components biplot of soils chemical content

Table 5. Soils fertility variability of irrigated and none irrigated fields

Sites		Ca (meq/100g)	Mg (meq/100g)	N (meq/100 g)	K (meq/100 g)	P (meq/100 g)	C (meq/100 g)	M.O (%)
Gaya Aval	IF	12.35	5.25	0.039	0.19	4.34	1.38	2.37
	NIF	6.9	0.93	0.027	0.17	2.9	1.93	2.11
Gaya Amont	IF	11.25	2.25	0.024	0.18	4.02	1.67	2.86
	NIF	6.15	1.22	0.006	0.11	2.73	0.35	0.61
Diambala	IF	14.05	2.66	0.042	0.04	2.34	1.61	2.78
	NIF	1.45	3.99	0.021	1.09	11.69	0.62	1.07
Sakondji Birni	IF	6.5	6.1	0.038	0.12	4.93	1.14	1.97
	NIF	2.6	4.98	0.011	0.12	1.08	0.42	0.72
Saguia	IF	9.65	5.87	0.043	0.19	1.19	1.14	1.97
	NIF	8.05	1.66	0.003	0.09	17.92	0.2	0.35
Saga	IF	8	2.52	0.014	0.22	15.15	0.57	0.97
	NIF	4	2.51	0.008	0.42	0.94	0.5	0.86
Bonfeba	IF	5.5	1.81	0.001	0.47	41.37	0.49	0.85
	NIF	16	1.72		0.17	12.25	0.19	0.32
Sebery	IF	12	5.64	0.011	0.12	1.29	0.62	1.07
	NIF	14.5	1.92	0.003	0.13	0.03	0.22	0.38
Toula	IF	16	2.39	0.004	0.08	4.41	0.36	0.62
	NIF	14.5	4.22	0.015	0.28	4.02	0.33	0.57
Ndounga	IF	17.5	4.26	0.062	0.11	0.49	0.35	0.6
	NIF	7.5	1.21	0.01	0.25	8.82	0.2	0.35

IF= irrigated field, NIF= Non irrigated field, M.O= Organic matter

Table 6. Irrigation water properties

Site	TDS	solubleNa/L (mg)	Na qty/ha/year (kg)
Saga	8.9	3.22	122
Sekondji Birni	9.78	5.75	218
Sebery	10.07	2.3	87
Bonfeba	9.81	5.52	209
Diambala	7.95	5.52	209
Gaya	10.74	5.75	218
Toula	10.04	2.99	113

TDS= total dissolved salt

silt content the irrigated fields were not different from non-irrigated fields.

The pH of both irrigated and non irrigated soils in the communities selected for the study are shown in Table 3. Apart from the soil at Bonfeba which was neutral in term of pH all the soils were acidic (pH < 7). The lowest pH in KCl of 3.5 was recorded in the two localities of Gaya. The pH in KCl at Saguia and Sakondji Birni were strongly acidic with pH below 5. In general, there was no significant difference in pH between irrigated and non irrigated plots within each selected field.

For all the sites, sodium adsorption ratio of irrigated fields (SAR IF) was significantly higher than sodium adsorption ratio of non-irrigated fields (SAR NIF) (P = 0.001) (Table 4). The greatest level of SAR was observed at Saga irrigated fields and the lowest at Saguia (Figure 1). Sodium content in irrigated fields was higher compared to non-irrigated fields. The exchangeable sodium percentage was also higher in irrigated compared to non-irrigated fields. The Na content and consequently the SAR and Na saturation were highest in the Saga soils.

The ratio Na/K ranged from 7.8 to 118.6 in the irrigated fields and from 4 to 71.7 in non-irrigated fields. The PAR was significantly higher in non irrigated fields than irrigated ones (P= 0.0263).

The CEC are significantly higher in irrigated schemes compared to non-irrigated ones (P= 0.001) However, at Bonfeba, the non irrigated fields have high values of CEC.

The electrical conductivity of irrigated fields (EC IF) is significantly higher than non-irrigated fields ($P < 0.001$). The EC ranged from 5.2dSm^{-1} at Sakondji Birni to 16.5 dSm^{-1} at Bonféba with an average of 7.7 dSm^{-1}. The non irrigated fields EC varied from 2.2 dSm^{-1} (Saga) to 8.5 dScm^{-1} at Bonféba with an average of 5 dSm^{-1}.

The principal component analysis showed that the first two components account for 98.24% of the variation. High Na/K ration is associated with high SAR and high TDS (Figure 2). The sites with high Na/K and high SAR were Saga IF (11), Toula IF (17).

Soils nitrogen content (Table 5) was significantly higher in irrigated fields than non-irrigated fields (P = 0.002), but no significant difference existed in the phosphorus content of the two types of soils.

The highest TDS (10.74 mg l^{-1}) was observed at Gaya and the lowest (7.95 mg l^{-1}) at Diambala (Table 6).

The Niger River contains other sodium (Na) like salts. The Na content ranged from 2.3 mg l^{-1} at Sebery to 5.75 mg l^{-1} at Gaya with an average of 4.23 mg l^{-1}. The total sodium quantity estimated to be deposited per hectare per year varied from 87 kg ha^{-1}/year to 218 kg ha^{-1}/year.

Discussion

Seventy percent (70%) of non irrigated fields have sandy soils, while eighty percent (80%) of irrigated field have clay and silt soil. The higher percentage of the irrigated fields were silty and clayey due to the fact that these irrigation schemes are located in the low lying areas of the Niger river. The FAO (FAO, 1994) reported that Sahelian soils are generally sandy with sand percentage varying between 71 to 99% at the surface layer. This is because most of the soils devoted to agriculture in the Sahel are upland sandy soils.

The results showed that the pH of all fields was lower than 5.6 except for Bonfeba. Soils formed under low rainfall conditions as in Niger tend to be basic. However, intensive farming over a number of years with nitrogen fertilizers or manures can result in soil acidification (Cliff, 2005; Moreira and Fageria, 2009). This may be the reason why the pH levels in irrigated soils were more acidic than non irrigated soil.

The high EC of irrigated fields (16.5dS/m at Bonfeba and 9dS/m at Saga) results in severe yield reduction of rice and this may explain why, in these two areas, fields are completely abandoned. This great EC level may partly be due to irrigation because irrigated fields have greater value of electrical conductivity compare to non-irrigated ones. However, some fields that have never been irrigated have also high EC. This is due to inherent soil salts composition.

The sodium adsorption ratio (SAR), as well as exchangeable sodium percentage (ESP), was significantly higher in irrigated fields than non-irrigated ones. This may be due to irrigation water which contains a Na that accumulate over years, can affect soils and cause severe permeability problems when applied to fine-textured soils (Bergaya *et al.*, 2006; Foundation, 2007). SAR and ESP are two different criteria that are currently recognized in the scientific literature as indices of salinity. However, the values obtained in this study are below the reported threshold of 12 (Cmol kg) for SAR

(Mohsen *et al*., 2009). According to Munshower (Munshower, 1994), SAR along with pH, characterize salt-affected soils. When the SAR rises to between 12 to 15, serious physical soil problems arise and plants have difficulty in absorbing water.

Sodium to potassium ratio was significantly higher in irrigated schemes than non-irrigated schemes despite application of K fertilizer in the irrigated rice fields. This could be attributed to the high addition of Na from the irrigation water. The higher PAR in non-irrigated fields was due to relative high potassium content in these soils.

The CEC of irrigated fields was significantly higher than that of non-irrigated fields. This was likely due to their higher basic cations added from the irrigation water.

Nitrogen content was higher in irrigated schemes than in non-irrigated fields because of fertilizer application. In the area, fertilizer was used only for rice cultivation.

Amount of dissolved substances, collectively called salts, are included in irrigation water. These salts derived from the weathering of rocks and soil (Ayers and Westcot, 1976; Miller and Donahue, 1995). Salts are added to the soil through irrigation, and a huge quantity of sodium from irrigation water is deposited (up to 200 kg of sodium per year per hectare) in rice fields. But these results do not reflect the soil actual salinity level. The salinity level is lower than could have been expected. This is because the degree of leaching was not known and was not taken into consideration in these calculations.

The cumulative effect of irrigation water that contains some salts and low permeability of irrigated fields soils, may make it not economically feasible for farmers to maintain low salinity levels. Thus, judicious selection of rice varieties that can withstand salt stress and produce satisfactory yields in such situations is imperative (Allison *et al*., 1954). Salinity also imposes osmotic stress on rice plants. Hence, the availability of water to plants is always a main factor under saline conditions. Thus, because of the osmotic effects that are additive with soil moisture tension the plant will stop growing when the soil dries. In such conditions in order to improve production, breeding programs should include, in addition to salinity tolerance, drought tolerance in rice varieties.

High electrical conductivity results in yield reduction. Thus electrical conductivity between 4-8 restricts rice yield (Allison *et al*., 1954). Hence, we need salt tolerant cultivars to boost rice productivity is these localities.

The exchange complex contains appreciable amounts of sodium in the irrigated fields of our study. Thus, the soil may become dispersed and puddle, leading to poor aeration and low water availability (McGeorge and Breazeale, 1938). Nutritional disturbance may also occur (Ratner, 1935). In such situations the exchange complex removes calcium from the root tissues of the plants and death may occurred because of calcium deficiency (Allison *et al*., 1954). Crop management practices for the safe use of such salt-affected soils primarily consists of growing suitable salt-tolerant crops (Ahmed and Malik, 2002). Appropriate rice genotypes, for satisfactory yield under existing saline conditions are needed (Toderich *et al*., 2008). Therefore breeding rice for salt tolerance combined with calcium uptake and sodium exclusion at the root level is necessary. Agronomic measures can also be undertaken to overcome the problem. This approach involves major engineering and soil amelioration processes which need lot of resources and are often out of the reach of small and marginal farmers.

The sodium adsorption ratio (SAR) and the exchangeable sodium percentage (ESP) were higher in irrigated fields compared to non irrigated fields. Salinity will make it more difficult for plants to absorb water from the soil. Some of the dissolved salts can also be toxic to plants. For instance, high levels of sodium and chloride in the soil solution are toxic to plants. This results in plant injuring such as leaf burning or leaf tissue drying. Thus it is necessary to breed salt tolerant rice varieties that combine salt exclusion at the tissue and cell level.

Conclusion

In this experimental study, soil samples with large variations of texture showed that all the soils were acidic. EC was significantly higher and is beyond 4dS/m and can go up to 16.5 in irrigated schemes. The sodium adsorption ratio (SAR), the exchangeable sodium percentage (ESP) and the cation exchange capacity (CEC) are also significantly higher in irrigated fields. Most farmer's rice fields soils were saline. Organic matter was present in higher quantities in farmers fields when non-irrigated fields had more potassium. Soil ions content may have been brought about partly by irrigation. The study showed that a large amount of salt can be deposited in soil trough irrigation. This led to salinization that severely affects soil productivity. Hence, salt tolerance varieties should be bred to enhance rice production in Niger.

References

Ahmed, R., Malik, K.A., 2002. Prospects for saline agriculture. Kluwer Academic Publishers, Dordrecht, Netherland. pp62.

Allison, L.E., Bernstein, L., Bower, C.A., Brown, J.W., Fireman, M., Hatcher, J.T., Hayward, H.E., Pearson, G.A., Reeve, R.C., Richards, A., Wilcox, K.V., 1954. Plant response and crop selection for saline and alkali soils. In: Richards, L.A. (Ed.), Diagnosis and Improvement of saline and alkali soils. United States Salinity Laboratory Staff, United States

Anderson, J.M., Ingram, J.S.I., 1993. Tropical Soil Biology and Fertility: a Handbook of Methods. CAB International, Wallingford, UK.

Anonymous, Niger Republic, 2016. Agriculture. 2016 ; Available from: https://sites.google.com/a/tcd.ie/republic-of-niger-mdp/home/agriculture.

Ayers, R.S., Westcot, D.W., 1976. Water Quality for Agriculture. FAO Irrigation and Drainage Paper No, 29 (Rev 1), Food and Agriculture Organization of the United Nations.

Bergaya, F., Lagaly, G., Vayer, M., 2006. Cation and Anion Exchange. In: Bergaya, F., Lagaly, G., Theng, B.K.G. (Eds.), Handbook of Clay Science, Developments in Clay Science. Elsevier, Amsterdam, pp. 979-1001.

Cliff, S., 2005. Efficient Fertilizer Use: Soil pH Management 20.

Day, R.P., 1965. Pipette method of particle size analysis: Methods of soil analysis. Agronomy 9, 553-562.

FAO, 1994. Le travail du sol pour une agriculture durable. FAO Soils Bulletin 69. FAO, Rome, 90

FAO, 2007. Niger presentation. http://www.fao.org/ag/AGP/AGPC/doc/Counprof/niger/niger.htm., Rome.

FAO, 2008. A Review of Risk Management Tools and Policies in Niger's Rural Sector FAO Rome.

FAO, 2009. Initiative on Soaring Food Prices. FAO Rome.

Foundation, W.R., 2007. Advanced topics in water chemistry and salinity: Sodium adsorption ratio. http://www.salinitymanagement.org.

INS, 2010. Institut national de la statistique/Niger.

Jacques, D., Guero, Y., Paul, F., Serge, V., 1994. Mineralogy of salt efflorescences in paddy field soils of Kollo, southern Niger. Geoderma 64, 57-71.

Karuppan, S., Minh-Long, N., 2010. Extent, impact, and response to soil and water salinity in arid and semiarid regions. Advances in Agronomy 109, 55-74.

MAE, 2001. Ministère de l'Agriculture et de l'Elevage de la République du Niger. Services d'Analyse de la Politique Agricole et de la Coordination Statistique. Niamey/ Niger. p. 96.

McGeorge, W.T., Breazeale, J.F., 1938. Soil structure effect: effect of puddle soils on plant growth. Ariz. Agri. Expt. Sta. Tech. Bul. 72, 413-447.

Miller, R.W., Donahue, R.L., 1995. Soils in Our Environment, Seventh Edition. Prudence Hall, Englewood, Cliffs, NJ. P. 323.

Mohsen, S., Majid, R., Borzoo, G.K., 2009. Prediction of Soil Exchangeable Sodium Percentage Based on Soil Sodium Adsorption Ratio. American-Eurasian J. Agric. & Environ. Sci. 5, 1-4.

Moreira, A., Fageria, N.K., 2009. Soil Chemical Attributes of Amazonas State, Brazil. Communications in Soil Science and Plant Analysis 40, 2912-2925.

Munshower, F.F., 1994. Practical Handbook of Disturbed Land Revegetation. Lewis Publishers, Boca Raton, Florida.

Murphy, J., Riley, J.P., 1962. A modified single solution method for determination of phosphates in natural waters. Anal. Chim. Acta 27, 31-36.

Norman, J.C., Kebe, B., 2007. African smallholder farmers: rice production and sustainable livelihoods. FAO, rome.

Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean, L.A., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. of Agric. Circ., 939.

Ratner, F.I., 1935. The influence of exchangeable sodium in the soil, on its properties as a medium for plant growth. Soil Sci. 40, 459-471.

Sant'Anna, R., 2000. Major soils for food production in Africa: *in, Soil tillage in Africa: needs and challenges*. FAO, Rome.

Toderich, K., Tsukatani, T., Shoaib, I., IMassino, I., Wilhelm, M., Yusupov, S., Kuliev, T., Ruziev, V., 2008. Extent of salt affected land in Central Asia: Biosaline agriculture and utilisation of salt affected resources. Discussion Paper No. 648 Kyoto Institute of Economic Research. pp 34.